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Predictors and Outcomes of Variability in Subjective Alcohol Intoxication among College Students: An Event-Level Analysis across Four Years

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Abstract

Background—Individual differences in subjective alcohol intoxication, as measured by laboratory-based alcohol challenge, have been identified as a phenotypic risk factor for alcohol use disorders. Further, recent evidence indicates that subjective alcohol response is also associated with event-level physiological consequences among college students, including blackouts and hangovers.

Methods—The current investigation tested predictors of and outcomes associated with subjective intoxication in the natural drinking environment. In a preliminary laboratory alcohol-challenge study (N = 53), we developed a brief measure of subjective alcohol intoxication for use in event level research. Participating students in the principal study (N = 1,867; 63% female; 54% Caucasian) completed 30 days of Web-based self-monitoring in each of the four college years.

Results—In the principal study, Generalized Estimating Equation analyses revealed that both lighter drinking and a family history of alcohol problems predicted greater subjective intoxication after accounting for estimated blood alcohol concentration (eBAC). Moreover, greater subjective intoxication during a given drinking episode was associated with negative alcohol-related consequences, illicit drug use, and unsafe sex, and at higher eBACs, was associated with aggression, sex, and property crime. Students who on average experienced greater subjective intoxication were also more likely to experience negative consequences and engage in illicit drug use, sex, unsafe sex, and aggression.

Conclusions—These findings suggest that both within-person variability and between-person individual differences in subjective intoxication may be risk factors for adverse drinking outcomes at the event level. Intervention efforts aimed at reducing problems associated with collegiate drinking may benefit from consideration both of who experiences greater subjective intoxication and of the situations in which they are more likely to do so.

Keywords

Subjective Intoxication; Subjective Response; Alcohol Abuse; College Students; Event-Level

Despite increasing awareness among researchers and college administrators, college student alcohol use remains both prevalent and problematic (Bachman et al., 1997; Hingson et al., 2009; NIAAA, 2002). Hingson and colleagues (2009) reported that 1,825 college students died in 2005 as a result of alcohol, an increase of 3% per 100,000 since 1998. Additionally, 599,000 college students are injured as a result of their drinking each year, and 646,000 more are assaulted by intoxicated fellow students (Hingson et al., 2005). Given these

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alarming figures, researchers have attempted to identify factors that increase students' risk of experiencing deleterious drinking-related consequences.

That some individuals respond more strongly than others to the intoxicating effects of alcohol has been recognized for several decades. Early research suggested that low subjective alcohol response was a risk factor for problematic long-term alcohol outcomes. When matched on typical drinking rates, individuals with a positive family history of alcohol use disorders (AUDs) display reduced subjective alcohol intoxication (Pollock, 1992), and approximately 60% of the variability in subjective intoxication can be explained by genetic factors (Heath et al., 1999). Further, this line of research suggested that individuals with reduced subjective alcohol response are more likely to develop an AUD later in life (Schuckit and Smith, 1996, 2000; Schuckit et al., 2007). Schuckit and colleagues have proposed that low levels of subjective response to alcohol serve as an intermediate phenotype, reflecting inherited risk for increased alcohol consumption and eventual AUD diagnosis (e.g., Schuckit et al., 2010).

Complicating this account, individuals who find alcohol intoxication more enjoyable may also be more likely to drink heavily. Indeed, heavier drinkers report greater response to the positively reinforcing effects (e.g., stimulation, vigor) of alcohol (e.g., King et al., 2002). In an attempt to integrate these findings, Newlin and Thomson (1990, 1999) proposed a differentiator model of subjective alcohol response and risk for AUDs. According to this model, those at risk for AUDs may experience greater response to the positively rewarding stimulant effects of alcohol, which typically occur as BACs increase, but lower response to the aversive sedative effects of alcohol, which typically increase as BACs descend.

Proximal Consequences of Differences in Subjective Alcohol Intoxication

Although past research has identified the distal drinking-related outcomes of individual differences in subjective intoxication (i.e., AUD diagnoses), recent evidence suggests that *greater* subjective intoxication may also be a risk factor for consequences more proximally, at the episode level. Specifically, a recent study demonstrated that college students who experienced greater subjective intoxication at the mid-point of their 21st birthday celebrations—across measures of both rewarding and aversive alcohol effects —were more likely to experience blackouts and hangovers as a result of those celebrations over and beyond the effect of final estimated BACs reached during the episode (Wetherill and Fromme, 2009). Although we know of no other studies testing similar relations, these findings suggest that subjective reports of greater intoxication may be associated with greater physiological response to alcohol independent of objective intoxication levels.

If greater subjective intoxication predicts negative physiological consequences over and beyond the effect of BAC, it may also provide incremental predictive power for other alcohol-related outcomes. Previous event-level investigations have demonstrated that college students are more likely to experience negative consequences (e.g., shame, missed classes, arrests) following drinking episodes in which they reach higher BACs (Neal and Carey, 2007). Further, at higher BACs college students are also more likely to engage in several behavioral risks, including risky sexual behaviors, aggression, and property crime (Neal and Fromme, 2007). These investigations did not, however, assess the effect of subjective intoxication relative to that of BAC. Thus, to our knowledge, no study has tested whether higher levels of subjective intoxication predict negative event-level outcomes beyond blackouts and hangovers.

Assessing Subjective Intoxication and Its Consequences in the Natural Environment

The vast majority of studies of subjective intoxication as an intermediate phenotype have used laboratory-based alcohol challenge paradigms (see Morean and Corbin, 2010 for a review). Whereas this methodology has a number of advantages, it has limitations as well. Notably, laboratory-based studies by definition do not capture drinking in the natural environment. The contexts of collegiate drinking vary but typically comprise social situations, and in contrast to laboratory studies, alcohol consumption often does not occur in a single dose and is not always constrained to relatively modest BACs (Brister et al., 2010; Neal and Carey, 2007; Wetherill and Fromme, 2009). In the current study, we investigated the predictors and outcomes of subjective intoxication in the natural environment using four years of Web-based daily diary assessments. The daily diary approach permits examination of the real-world consequences and behavioral risks that may occur as a result of alcohol intoxication.

The first aim of the present study was to replicate and extend previous associations between subjective intoxication and both family history of AUDs and typical alcohol consumption. Although subjective intoxication as a function of family history and typical consumption has been extensively tested in response to laboratory alcohol challenge, these studies often could not isolate the effect of chronic tolerance acquired as a result of experience with intoxication. One methodological approach to examining tolerance has been to employ retrospective assessments of initial intoxication experiences (e.g., Morean and Corbin, 2008; Schuckit et al., 1997a; Schuckit et al., 1997b). Retrospective reports, however, can have limited reliability and validity, and retrospective reports of subjective intoxication typically display only small-to-moderate associations with ratings made during alcohol challenge (Schuckit et al., 1997b). The current study therefore attempted to replicate previous findings (i.e., from family history and typical drinking comparisons) in the natural environment using an event-level methodology and, further, to test whether experience with alcohol across the college years can influence ratings of subjective intoxication. To that end, we first developed a brief measure of subjective alcohol intoxication in a laboratory-based alcohol-administration study. We then employed that measure to test our hypotheses using a daily diary methodology.

The second aim of the current investigation was to test whether individual differences in subjective intoxication—after accounting for BAC as estimated from self-report (eBAC) —predict negative outcomes as they occur at the event level. As an extension of Wetherill and Fromme's (2009) demonstration that greater subjective intoxication predicted blackouts and hangovers, we tested whether greater subjective intoxication would increase the likelihood that college students experience negative drinking-related consequences and behavioral risks. One advantage of the present methodology is the ability to differentiate the between- from the within-person effects of subjective intoxication. That is, the daily self-monitoring approach can distinguish between the risk of negative outcomes for students who, holding eBAC constant, on average reach greater levels of subjective intoxication (between-person) and the risk of outcomes for students on days when they reach greater-than-their-average subjective intoxication (within-person).

In summary, we conducted two studies to test predictors and outcomes of variability in subjective alcohol intoxication. First, in a lab-based preliminary study, we examined the reliability and validity of a brief measure of subjective intoxication for event-level use. In the principal study, we then tested our specific hypotheses regarding predictors (i.e., family history of alcohol problems, typical alcohol consumption) and outcomes (i.e., alcohol-

related consequences, behavioral risks) of subjective intoxication using an event-level daily diary methodology.

Preliminary Study

Method

Participants and procedure—Included participants were taken from a larger laboratory-based alcohol challenge study of young adult social drinkers recruited from the community. The larger study was primarily intended as a test of the association between alcohol intoxication and aggressive responding in dating situations, the results of which have not yet been published. Although we report here results from the alcohol condition only, participants (total $N = 150$) were randomly assigned to alcohol, placebo, or no alcohol control conditions. After providing informed consent, participants were tested using an Intoxilyzer 5000 (CMI, Inc., Owensboro, KY) to ensure initial breath alcohol concentrations (BrACs) of .00. Female participants also provided urine pregnancy tests; no participants tested positive. Participants in all conditions completed an assessment battery before consuming beverages in groups of up to four in a simulated bar environment.

Participants in the alcohol condition ($n = 53$; 49% female; 64% White, 17% Hispanic or Latino, 9% Asian-American, and 9% multi-ethnic) were 22.82 years old on average ($SD = 1.92$). Over a 30-minute period in the simulated bar, they consumed three beverages consisting of 80-proof vodka and mixer to achieve a targeted peak BrAC of .08 g/dl. Following a 20-minute absorption period, we recorded BrAC and subjective intoxication and BAES ratings. Participants were then separated into testing rooms to complete a protocol consisting of spoken responses to auditory aggression cues, the results of which are not reported here. At 60 and 90 minutes following alcohol consumption, we again recorded BrAC and subjective intoxication and BAES ratings. Following the completion of the protocol, participants remained in the lab until they provided BrACs of less than or equal to .02, after which they signed contracts ensuring that they would not drive for the remainder of the night and were either picked up by friends or family or were provided transportation home by study staff.

Measures—As a brief measure of subjective intoxication, participants rated their level of intoxication on a visual analogue scale from 0 = *not at all drunk* to 100 = *extremely drunk*. Participants additionally completed the Biphasic Alcohol Effects Scale (BAES; Martin et al., 1993), a widely used and well-validated measure of subjective response to alcohol challenge. The BAES comprises two subscales assessing the stimulant ($\alpha = .96$) and sedative ($\alpha = .89$) effects of alcohol with seven items each.

Results and Discussion

As a manipulation check, we examined the peak BrAC achieved across the assessments. At the 60 minute assessment, BrACs were at their highest point ($M = .079$ g/dl, $SD = .01$), which closely approximated the target BrAC of .08 g/dl. Our first objective was to test the reliability of the brief measure of subjective intoxication. As shown in Table 1, subjective intoxication demonstrated good test-retest reliability within a single drinking episode. Indeed, correlations across time for subjective intoxication compared favorably to cross-time correlations for the BAES Sedation and Stimulation subscales. Second, we tested the convergent validity of subjective intoxication by examining correlations with the BAES. Across all three assessment points, subjective intoxication was consistently and strongly associated with BAES Sedation but was not significantly associated with BAES Stimulation. BAES Sedation and Stimulation scores were not associated at any assessment.

In sum, these preliminary analyses demonstrated that the visual analogue scale measure of subjective intoxication was reliable across time and that it appeared to most strongly assess the sedative effects rather than the stimulant effects of alcohol. This pattern of results is consistent with findings for several of the most commonly used measures of subjective response to alcohol, including the Subjective High Assessment Scale (Ray et al., 2009) and the Self-Rating of the Effects of Alcohol (Chung and Martin, 2009; Morean and Corbin, 2008).

Principal Study

The preliminary study established the reliability and convergent validity of a brief measure of subjective alcohol intoxication. This measure appeared to most strongly assess the sedative effects of alcohol, which previous lab-based research suggests are less strongly experienced among family history positive and heavier drinking young adults. We next used the measure to test our primary hypotheses using a Web-based daily diary study across the four college years. Specifically, we tested the following hypotheses: (1) controlling for eBAC as calculated from self-reported drinking patterns, subjective levels of intoxication will decrease across the college years as a function of acquired tolerance; (2) controlling for eBAC, family history positive participants and heavier drinkers will report lower subjective intoxication; (3) both greater daily (within-person) and average (between-person) levels of subjective intoxication will predict an increased likelihood of negative drinking consequences over and beyond eBAC; and (4) both greater daily and average levels of subjective intoxication will predict an increased likelihood of engaging in behavioral risks over and beyond eBAC.

Method

Participants—First-time students between the ages of 17 and 19 in the incoming class of 2004 at a large southwestern university (N = 6,290; 94% of the incoming class) were invited to participate in a longitudinal study during the summer prior to matriculation. Of the 4,832 interested students (76% of those eligible) who also met criteria for being unmarried, 2,985 were randomized to complete a Web-based pre-college survey followed by semi-annual assessments.1 Of this randomized sample, 75% (N = 2,245) provided informed consent and were therefore additionally invited to provide daily self-monitoring for 30 consecutive days in each of the four years following matriculation. For further information regarding participant recruitment and other procedures for the longitudinal study, please see Corbin and colleagues (2008b) and Hatzenbuehler and colleagues (2008).

Of the students invited into the daily monitoring protocol, 2,016 participated during at least one year. To ensure reliable responding without introducing bias due to over-exclusion or inclusion of noncompliant participants, we included data in this study from participants who completed at least 14 days of monitoring within a given year (n = 1,867 individuals with 148,097 unique observations). We also excluded 234 outlying observations (0.16% of all observations) on which eBACs exceeded .4. Our final sample therefore included 1,867 individuals (63% of the randomized sample; 30% of eligible students in the incoming class of 2004) with an average of 79 days monitored (range: 14-120) over all four years. The data comprised 147,863 total observations, including 20,342 drinking days among 1,406 drinkers. The final sample was 63% female, 54% White, 19% Asian or Asian-American, 15% Hispanic or Latino, 4% African-American, and 7% multi-ethnic or other ethnicities.2 In the summer prior to matriculation, the average age was 18.41 years (SD = 0.35).

[1]Of those not assigned to the biannual assessment condition, 976 participants were randomized to complete surveys in the fall of years 1 and 4, and 810 were randomized to complete a survey in the fall of year 4 only.

Included participants did not differ from participants in the longitudinal cohort who were excluded from the current analyses ($N = 380$) in age, $t(2,245) = 1.59$, $p = .11$, $d = .09$, ethnicity, $\chi^2(7) = 9.90$, $p = .19$, or family history of alcohol problems, $\chi^2(1) = 0.91$, $p = .34$. Included participants were, however, more likely to be female, $\chi^2(1) = 33.56$, $p < .001$.

Measures—Participants reported demographic and family history information in the pre-college survey. All other measures were assessed via daily self-monitoring (see below). We assessed family history of alcohol problems with the Family History Tree questionnaire (Mann et al., 1985), through which participants categorized siblings, parents, and grandparents into the following categories: *non-drinker*, *social drinker*, *possible problem drinker*, and *definite problem drinker*. Participants with at least one definite problem-drinking family member were classified as having a positive family history of alcohol problems (22%; $n = 415$). All other participants were classified as having a negative family history.

Self-monitoring protocol—Beginning in August of the first year, we randomly assigned 40–43 participants to begin 30 consecutive days of Web-based monitoring each week, and we used the same start dates for the remaining 3 years. To complete the daily monitoring assessment, participants logged into a secure Web site (maintained by DatStat, Seattle, Washington), on which they viewed their 30-day monitoring period in calendar form. We encouraged participants to log into the monitoring site daily but granted access to the previous seven days on the calendar in order to minimize retrospective bias and missing data. For each day, participants first reported time-varying demographic characteristics (e.g., weight, relationship status). Next, participants answered a series of questions regarding that day's alcohol consumption. Participants reported the number of discrete drinking occasions, the number of standard drinks (defined as 12 oz of beer, 5 oz of wine, or 1.5 oz of liquor in a shot or mixed drink) consumed, and the duration of the heaviest drinking occasion. Participants also reported the level of subjective intoxication obtained during the day's heaviest drinking episode on a visual analogue scale from 0 = *not at all drunk* to 100 = *extremely drunk*. Using self-reported gender, weight, and drinking quantity and duration, we calculated eBAC following the procedure recommended by Matthews and Miller (1979). This procedure has been recommended as a method of estimating BAC when breath alcohol concentrations (BrACs) are not available (Hustad and Carey, 2005). It has been used in several recent event-level studies (e.g., Neal and Carey, 2007; Neal and Fromme, 2007; Ray et al., 2010) and has demonstrated strong associations with BrAC (Hustad and Carey, 2005). See Table 2 for aggregate summary statistics for eBAC and subjective intoxication.

Participants next reported whether they experienced any emotional (e.g., regret, anxiety), social (e.g., rejection, damage to reputation), physical (e.g., hurt self or other), disciplinary (e.g., caught, arrested, punished), financial (e.g., spent or lost money), or academic (e.g., missed class, failed exam) consequences as a result of their drinking. Following Neal and Carey (2007), we combined responses to the consequence items to create an index of whether participants experienced at least one negative consequence following a given drinking episode. Finally, participants reported whether they had engaged in a variety of behavioral risks on a given monitoring day, including illicit drug use (e.g., marijuana, ecstasy), any sexual behavior (e.g., oral, vaginal, or anal), unsafe sexual behavior (e.g., did not talk about or use protection), aggression (e.g., became angry, engaged in verbal/physical fights), gambling (e.g., casino, sports), and property crime (e.g., stole, destroyed property). For each endorsed behavioral risk, participants additionally reported whether the behavior

[2]Although the results are not reported in this article, in analyses controlling for ethnicity, virtually none of the substantive effects reported here differed in either magnitude or significance. The results of these analyses are available upon request from the first author.

occurred prior to drinking, while drinking, or both. Table 3 presents the prevalence of alcohol-related consequences and behavioral risks across the four college years.

Data analytic strategy—We first examined aggregate summary statistics for alcohol use and subjective intoxication across the four monitoring periods. After these preliminary analyses, because the event-level outcomes (i.e., subjective intoxication, alcohol-related consequences, and behavioral risks) were nested within individuals and non-normally distributed, we tested our hypotheses using Generalized Estimating Equations (GEEs; Hardin and Hilbe, 2003). This analytic approach accommodates nested data by accounting for intra-individual correlations and additionally can permit unequal numbers of observations across individuals without biasing results (Hardin and Hilbe, 2003). We estimated two-level models (monitoring days nested within individuals) and treated monitoring year as a covariate. In all models, we included indicator variables for each day of the week, with Sunday as the reference day, to control for day-to-day variation in alcohol use, consequences, and behavioral risks. We also included within-year monitoring day to test and control for reactivity effects. Given our eight dependent variables (i.e., subjective intoxication, alcohol-related consequences, and six behavioral risks) and moderate number of independent variables, we employed a modified Bonferroni adjustment, in which the *a priori* alpha level was set to .05/8 = .00625. All analyses were conducted in Stata 10.1 (StataCorp, 2009).

In order to disentangle the effects of within-person, episode-to-episode variation in subjective intoxication and eBAC from the effects of between-person differences in typical subjective intoxication and eBAC, we used a person-centered approach to the event-level analyses. Specifically, we entered both daily deviations from average levels of subjective intoxication and eBAC *and* average levels across monitoring periods into all models. Daily subjective intoxication and eBAC therefore reflect the within-person effect of deviation from typical levels of intoxication, whereas average subjective intoxication and eBAC reflect the between-person effect of typical intoxication. To aid the interpretations of odds ratios, we multiplied average and daily eBAC by 100, meaning that odds ratios for these variables reflect the increase in odds of outcomes associated with a .01 increase in eBAC. Similarly, we divided both daily and average subjective intoxication ratings by 10. Odds ratios for subjective intoxication variables represent the increase in odds of outcomes associated with a 10-point increase in subjective intoxication. Participants reported that between 6.0% (aggression) and 10.2% (any sexual behavior) of behavioral risks occurred prior to alcohol consumption. In these instances, we set the subjective intoxication and eBAC values for that day to zero.

Our first two hypotheses involved the prediction of subjective intoxication from monitoring year (Hypothesis 1) and from family history and typical alcohol consumption (Hypothesis 2). We estimated a GEE model predicting daily subjective intoxication using the Gaussian reference distribution and identity link, which is appropriate for continuous data. In addition to day of week, monitoring day, and monitoring year, this model included gender, family history of alcohol problems, and average and daily eBAC as predictors. Because there was no variability in subjective intoxication or eBAC on non-drinking days, the model was limited to the 20,342 days on which drinking occurred among 1,406 participants.

Our second two hypotheses concerned the predictive validity of subjective intoxication for alcohol-related negative consequences (Hypothesis 3) and behavioral risks (Hypothesis 4). We estimated seven separate models predicting the occurrence of consequences and the six behavioral risks with a GEE extension of binary logistic regression, using the binomial distribution and logit link. This specification permits the use of odds ratios (i.e., exponentiated coefficients) as a measure of effect size. In addition to the variables discussed

above, these models additionally included daily and average subjective intoxication and a daily eBAC × daily subjective intoxication interaction term. Because there was no variability in alcohol-related consequences on non-drinking days, we limited the consequence model to drinking days only.

Finally, the concurrent assessment of all measures leaves open the possibility that participants used the consequences and behavioral risks they experienced as indicators of their level of intoxication. Thus, associations between daily subjective intoxication and outcomes might reflect participants' attributions (e.g., "if I engaged in unsafe sexual activities, I must have been drunk"). Although measures of drinks consumed and subjective intoxication preceded the outcome items in the daily diary, participants may have learned to consider negative outcomes when presented with the subjective intoxication item. If this learning occurred, one would expect that the association between daily subjective intoxication and outcomes would increase across time. In order to test and account for this possibility, we included a monitoring day X subjective intoxication interaction term in models predicting consequences and behavioral risks.

Results and Discussion

Change in estimated BAC and subjective intoxication across the college years—As shown in Table 2, participants increased their drinking days per monitoring period across the four monitoring years. As a result, their average eBACs were higher in the later years. Despite drinking more frequently across the college years, however, participants were no more likely to reach higher eBACs on drinking days during later years. In contrast, participants decreased in their reported subjective intoxication on drinking days from the first to the fourth year.3

Predictors of subjective intoxication—The model predicting levels of subjective intoxication on drinking days was significant overall, $\chi^2(12) = 21{,}915.84$, $p < .001$. See Table 4. Consistent with previous findings, participants reported greater subjective intoxication on days on which they reached higher eBACs. This model additionally supported the hypothesis that experience with alcohol consumption would reduce ratings of subjective intoxication. Controlling for the effects of variation in eBAC, participants experienced reduced subjective intoxication in later monitoring years.

We hypothesized that subjective intoxication would differ as a function of two individual difference variables (i.e., family history and average eBAC). In contrast to previous research suggesting that individuals with positive family histories of alcohol problems experience a lower level of response to alcohol, when we controlled for eBAC, family history positive participants experienced greater subjective intoxication. As predicted given that our measure largely assessed the sedative effects of alcohol, heavier drinkers (i.e., those with greater average eBACs) reported lower subjective intoxication. In addition, men reported greater subjective intoxication relative to women. Finally, we found no evidence of an assessment reactivity effect on subjective intoxication. That is, there was no effect of monitoring day on ratings of subjective intoxication.

Estimated BAC, subjective intoxication, and alcohol-related consequences—As shown in Table 4, the model predicting negative alcohol-related consequences on drinking days was significant overall, $\chi^2(12) = 1{,}825.78$, $p < .001$. Within-person daily deviations from average eBAC and subjective intoxication were both associated with

[3]Although GEE analyses permit the inclusion of participants with partially incomplete data, we examined whether retention in the study by year four was related to study variables assessed in year one. In both simultaneous and independent binary logistic regression models, neither greater drinking nor greater subjective intoxication predicted study attrition, *p*s > .06.

increases in the likelihood of experiencing any negative consequence. Specifically, a .01 increase in eBAC was associated with a 4% increase in the odds of experiencing any consequence, whereas a 10-point increase in subjective intoxication was associated with a 24% increase in the odds of a consequence. The interaction between daily eBAC and daily subjective intoxication did not reach significance. As shown in Figure 1, in the simultaneous model, the effect of daily subjective intoxication on the likelihood of experiencing negative consequences was stronger than the effect of daily eBAC (as evidenced by a steeper slope).

Beyond daily deviations in eBAC and subjective intoxication, those participants who experienced greater subjective intoxication on average (i.e., the between-person effect) were also more likely to experience negative consequences (see Table 4). In contrast, there was no association between the likelihood of negative consequences and between-person individual differences in average eBAC. Neither gender nor family history of alcohol problems were associated with differences in risk for negative consequences, and the likelihood of experiencing negative consequences did not significantly change as a function of monitoring year. Finally, participants were less likely to report consequences on later monitoring days, suggesting a modest assessment reactivity effect.

Estimated BAC, subjective intoxication, and behavioral risks—All models predicting behavioral risks (i.e., illicit drug use, any sexual behavior, unsafe sexual behavior, aggressive behavior, gambling, and property crime) were significant, all $\chi^2(16) > 324.35$, *p*s < .001. See Table 5 for drug use, any sex, and unsafe sex and Table 6 for aggression, gambling, and property crime. When accounting for daily and average eBAC, greater within-person daily subjective intoxication was associated with an increased likelihood of engaging in illicit drug use, any sexual behavior, and unsafe sexual behavior but not aggression, gambling, or property crime. A 10-point deviation from average subjective intoxication was associated with an 8%, 5%, and 8% increase in the odds of drug use, sex, and unsafe sex, respectively. In contrast, over and beyond subjective intoxication, within-person daily eBAC was positively associated with a greater likelihood of aggression only, and daily eBAC was associated with a decreased likelihood of any sexual behavior. Specifically, a .01 increase in daily eBAC was associated with a 2% increase in the odds of aggression and a 1% decrease in the odds of engaging in any sexual behavior.

The effects of within-person daily subjective intoxication and eBAC on any sexual behavior, aggression, and gambling were qualified by significant subjective intoxication × eBAC interactions. As shown in Figure 2, the associations between daily subjective intoxication and sex, aggression, and property crime were stronger when participants reported higher eBACs. Thus, although the main effect of daily subjective intoxication on aggression and property crime was non-significant, the likelihood of engaging in either at high eBACs was greater among those reporting greater daily subjective intoxication.

Additionally, after accounting for daily SI and eBAC, participants who on average reported greater subjective intoxication (i.e., between-person individual differences in subjective intoxication) were more likely to use illicit drugs, have sex and unsafe sex, and act aggressively. Heavier drinkers (i.e., those with greater between-person average eBACs) were more likely to gamble but were not more likely to engage in any other behavioral risks.

Family history, gender, and behavioral risks—We found differences in behavioral risks as a function of family history of alcohol problems and gender. Participants with a positive family history of alcohol problems had 112% higher odds of illicit drug use, 31% higher odds of any sexual behavior, 66% higher odds of unsafe sexual behavior, 21% higher odds of aggression, and 47% higher odds of property crime. There were no differences in gambling as a function of family history. These results are generally consistent with

previous findings that family history positive youth are more likely to engage in a variety of behaviors on the externalizing spectrum (Hussong et al., 2010; Sher, 1997). Relative to women, men had 307% higher odds of gambling, 55% higher odds of property crime, and 43% higher odds of illicit drug use. In contrast, men had 41% lower odds of any sexual behavior, 33% lower odds of unsafe sexual behavior, and 29% lower odds of aggression. Finally, we found evidence for a modest assessment reactivity effect. The odds of endorsing each behavioral risk decreased between 1% and 6% per monitoring day within a given year.

Change in the associations between subjective intoxication and outcomes across the monitoring periods—If participants learned over the course of the monitoring periods to consider whether or not they experienced negative consequences of drinking or engaged in behavioral risks in judging their level of intoxication, one would expect that the associations between within-person daily subjective intoxication and outcomes would increase in strength across time. We found little evidence to support this explanation. Monitoring day significantly interacted with daily subjective intoxication to predict aggression and gambling. Monitoring day did not, however, moderate the association between daily subjective intoxication and negative consequences, nor the associations between daily subjective intoxication and illicit drug use, sex, unsafe sex, or property crime. In sum, monitoring day did not appear to influence the significant effects of daily subjective intoxication.

General Discussion

The first aim of this investigation was to test whether experience with alcohol consumption would lower ratings of subjective intoxication. We found support for this hypothesis in that participants increased the frequency with which they consumed alcohol and—holding eBAC constant—also reported lower levels of subjective intoxication in the later years of college. Thus, individual differences in subjective intoxication, at least regarding the sedative effects of alcohol, may not be independent of past alcohol use and may in part reflect the development of chronic tolerance to the effects of alcohol. Future research aimed at identifying predictors of subjective intoxication should account for experience with alcohol intoxication.

Second, we attempted to replicate previous findings regarding correlates of individual differences in subjective intoxication. Accounting for the effects of family history status, college students who drank more on average experienced lower subjective intoxication. Given that our measure appeared to largely assess the sedative dimension of subjective intoxication, this finding is consistent with prior evidence that heavier drinkers experience the aversive sedative effects less than do lighter drinkers (e.g., King et al., 2002). In contrast to our expectations, however, college students with a family history of alcohol problems also reported greater levels of subjective intoxication when accounting for levels of drinking. That is, we failed to replicate alcohol-challenge findings that family history positive individuals experience lower levels of subjective intoxication (see Pollock, 1992 for a review). We see several possible explanations for this failure to replicate previous findings. First, accounting for the potential confounds of typical consumption and experience may have affected the relation between family history and subjective intoxication. In models not reported here in which we removed the average eBAC and monitoring year variables, however, we found a similar effect of family history. Second, contextual differences between laboratory-based alcohol-challenge studies and real-world alcohol consumption may have differentially affected participants with and without a family history of alcohol problems. Future investigations are needed to determine whether this possibility helps explain discrepant current findings.

Subjective Intoxication Outcomes

The third and fourth aims of this study were to determine the proximal outcomes of greater subjective intoxication. We found support for both between-person and within-person effects when controlling for eBAC. College students who tended to experience greater subjective intoxication on average (i.e., the between-person effect) were more likely to experience negative alcohol-related consequences when they drank, and they also were more likely to engage in specific behavioral risks such as illicit drug use, sex, unsafe sex, and aggression. Moreover, in drinking episodes when they experienced greater subjective intoxication (i.e., the within-person effect), college students were more likely to experience negative consequences, use illicit drugs, have sex, and have unsafe sex. Significant interactions between daily eBAC and subjective intoxication demonstrated that during episodes in which participants reached higher eBACs, those who reported greater daily subjective intoxication were more likely to have sex, act aggressively, and commit property crime.

In contrast to the above results, we found limited effects of eBAC on outcomes when accounting for daily and average subjective intoxication. Daily eBAC predicted an increased likelihood of negative consequences, although this effect was weaker than the effect of subjective intoxication on consequences. Additionally, on days when they reached higher eBACs college students were more likely to act aggressively but less likely to have sex. Daily eBAC did not predict any other behavioral risks. Heavier drinkers (i.e., those with higher average eBACs) were more likely to gamble but were not more likely to engage in any other behavioral risks.

In addition to the family history associations discussed above, one additional aspect of the current results may at face appear to conflict with evidence for an element of Schuckit and colleagues' low level of response model (LLRM). Specifically, we found that students who on average experienced greater response on the sedative dimension of subjective intoxication (i.e., the between person effect) were more likely to experience a number of short-term negative consequences after accounting for BACs reached. In contrast, evidence for the LLRM has demonstrated that *lower* alcohol responders are more likely to develop alcohol problems and alcohol use disorders over subsequent years (Schuckit and Smith, 1996, 2000; Schuckit et al., 2007). The LLRM proposes a causal chain in which low responders must consume more alcohol to reach desired alcohol effects. As a consequence of their greater consumption, they develop tolerance, withdrawal, and—eventually—addiction.

Our findings, in contrast, crucially involve associations between subjective intoxication and event-level outcomes *when controlling for the amount of alcohol consumed*. That is, they suggest that among those who reach identical BAC levels, those who on average report greater subjective intoxication will be more likely to experience short-term negative consequences. Interestingly, these results may actually compliment the LLRM. Whereas the theoretical mechanism underlying the LLRM is the need for greater consumption to achieve desired alcohol effects, the current findings suggest that low responders may additionally be more likely to avoid negative outcomes at a given BAC level relative to their higher-responding peers. In addition to the impelling effect of low response predicted by the LLRM, low responders may additionally experience fewer aversive short-term outcomes when holding BAC constant, which may increase their confidence in the ability to consume greater quantities of alcohol without negative consequences.

Implications

The current findings suggest that greater response to at least the sedative dimension of subjective intoxication may lead college students to experience a variety of negative outcomes. An outstanding question, then, is why greater subjective intoxication predicts consequences and behavioral risks. Taken together with previous associations between subjective intoxication and greater physiological alcohol effects (Wetherill and Fromme, 2009), the current findings suggest that individual differences in subjective response may reflect differences in the degree to which individuals are affected by alcohol. Alcohol intoxication has several demonstrable psychological effects, including reduced perceptions of risk (Fromme et al., 1997) and limited cognitive control, as reflected by diminished behavioral inhibition and working memory capacity (Casbon et al., 2003; Curtin and Fairchild, 2003). These effects may help explain why intoxicated individuals can be more likely to engage in risky behaviors (Cooper, 2006; MacDonald et al., 2000; Moss and Albery, 2009). Alcohol also exerts a variety of additional pharmacological effects on the brain, including stimulating aspects of the reward system (Spear, 2002). The hedonic impact of alcohol might additionally contribute to adverse results. Although speculative at this point, we propose that subjective intoxication may be an index of individual differences in actual impairment, which leads to a multitude of negative drinking outcomes.

Limitations

We see three chief limitations to this investigation. First, given the burden associated with up to 120 daily self-reports, we assessed subjective intoxication with a single-item visual analogue scale. As demonstrated in the preliminary study, this measure was reliable, and in the principal study it demonstrated expected associations (e.g., with eBAC) and considerable predictive validity. The results of the preliminary study suggest, however, that the measure largely captured the aversive sedative effects of alcohol rather than the pleasurable stimulant effects (Martin et al., 1993; Ray et al., 2009). Given previous findings that both the stimulant and sedative dimensions of subjective intoxication predicted blackouts and hangovers (Wetherill and Fromme, 2009), further research is needed to determine whether selective stimulant or sedative responses differentially predict other negative event-level drinking outcomes.

Additionally, our daily self-monitoring design was retrospective, if only over brief periods of time, and cross-sectional. We therefore can make no causal conclusions regarding associations between subjective intoxication and negative outcomes. Indeed, one alternative explanation is that participants used negative outcomes as personal indices of daily subjective intoxication, which would account for associations between daily—but not average—subjective intoxication and outcomes. We made several efforts to account for this possibility. First, we designed the daily diary such that the measure of subjective intoxication preceded the measures of consequences and behavioral risks. Second, we included a monitoring day X daily subjective intoxication interaction term to test for the possibility that over time, participants began to use negative outcomes to determine their assessments of subjective intoxication. We found very little evidence that experience with the daily monitoring protocol affected the associations between subjective intoxication and outcomes. Our methodology cannot, however, entirely rule out this alternative. Experience sampling and randomized, controlled alcohol-challenge studies could rule out this attributional explanation for the association between daily subjective intoxication and outcomes, but neither methodology is without weaknesses, including potentially reduced reliability at higher BACs and decreased external validity, respectively. Given the imperfections of each approach, converging evidence for the role of subjective intoxication in negative outcomes across multiple methodologies would be ideal.

Finally, our event-level methodology required that we rely on self-report to measure both subjective intoxication and eBAC. Although self-report assessments of both variables have been validated in relation to physiological measures (e.g., Hustad and Carey, 2005; Schuckit, 1985; Schuckit et al., 1987), future research assessing the physiological bases of individual differences in subjective intoxication is needed to determine the mechanisms through which increased risk for event-level outcomes operates. Further, evidence from laboratory-based studies in which breath alcohol levels can be assessed would provide additional support for our conclusions.

Conclusions

This investigation demonstrated that subjective alcohol intoxication—at least on the sedative dimension—is associated with both stable individual differences (e.g., family history of alcohol problems, gender) and an individual's experience with alcohol intoxication over time. Perhaps more importantly, in conjunction with previous findings that subjective intoxication predicts blackouts and hangovers (Wetherill and Fromme, 2009) and greater within-episode consumption (Corbin et al., 2008a; Ray et al., 2010; Wetherill and Fromme, 2009), the current results are among the first to suggest that variability in subjective intoxication represents a risk factor for negative alcohol-related consequences and behavioral risks at the event level. Subjective reports of intoxication may improve our ability to predict which college students will experience negative drinking outcomes and when those outcomes will occur over and beyond the effect of estimated BAC. Students with a tendency towards greater subjective intoxication may be at risk for negative outcomes. Further, students may be particularly likely to experience consequences or behavioral risks when they experience greater-than-average subjective intoxication. Rapid alcohol consumption and drinking in social contexts can increase perceived intoxication (Martin and Earleywine, 1990; Ray et al., 2010); these behaviors may be particularly useful targets for intervention. In sum, negative outcomes may be less a matter of how much alcohol a student has consumed and more a matter of how strongly alcohol is affecting his or her functioning.

Acknowledgments

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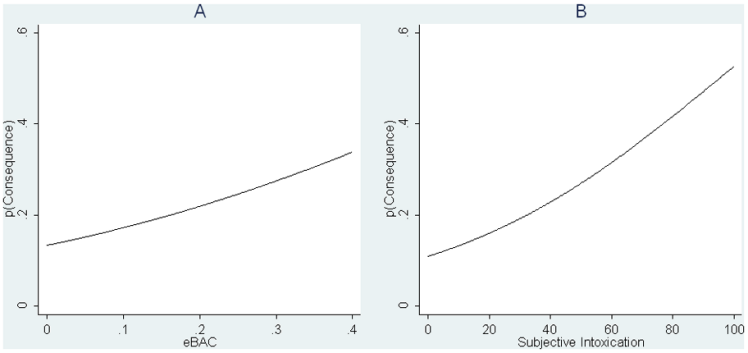

Figure 1.
Probability of alcohol-related consequences as a function of daily estimated blood alcohol concentration (eBAC; Panel A) and subjective intoxication (Panel B) in a simultaneous model.

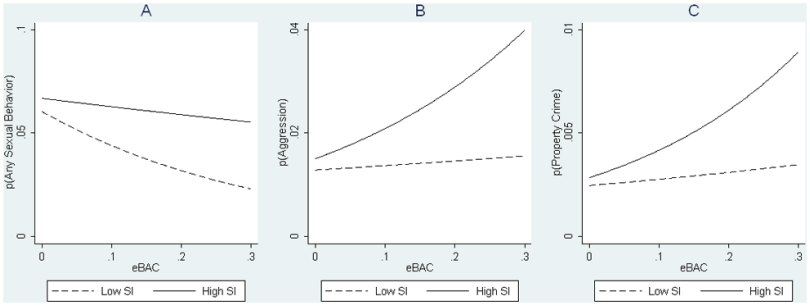

Figure 2.
Probabilities of any sexual behavior (Panel A), aggression (Panel B), and property crime (Panel C) as a function of daily estimated blood alcohol concentration (eBAC) one standard deviation above and below the mean of daily subjective intoxication (SI).

Table 1

Correlations among Subjective Alcohol Response Measures in the Preliminary Study

Measure	1	2	3	4	5	6	7	8
Subjective intoxication								
1. 20 minutes after consumption	-							
2. 60 minutes	.77†	-						
3. 90 minutes	.83†	.93†	-					
BAES-Sedation								
4. 20 minutes	.45†	.44†	.38*	-				
5. 60 minutes	.50†	.57†	.51†	.78†	-			
6. 90 minutes	.55†	.70†	.67†	.55†	.80†	-		
BAES-Stimulation								
7. 20 minutes	.24	.16	.14	.22	.17	.27	-	
8. 60 minutes	.15	.16	.11	.22	.12	.07	.67†	-
9. 90 minutes	.01	.04	.05	.05	.08	.02	.60†	.72†

*$p < .00625$.

†$p < .001$.

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Table 2

Aggregate Summary Statistics for Subjective and Objective Intoxication by Year of Daily Monitoring

Variable	Year 1 (*n* = 1572) *M* (*SD*)	Year 2 (*n* = 1465) *M* (*SD*)	Year 3 (*n* = 1329) *M* (*SD*)	Year 4 (*n* = 922) *M* (*SD*)
Monitoring days	27.82_{ab} (3.75)	28.07_{a} (3.67)	27.89_{ab} (3.87)	27.88_{b} (3.85)
Drinking days				
Across all participants	2.71_{a} (3.80)	3.41_{b} (4.56)	4.91_{c} (5.34)	5.62_{d} (5.38)
Among drinkers only[a]	4.81_{a} (3.99)	5.59_{b} (4.71)	6.85_{c} (5.21)	7.28_{d} (5.08)
Average eBAC				
Across all days	$.010_{a}$ (.02)	$.013_{b}$ (.02)	$.017_{c}$ (.03)	$.017_{c}$ (.02)
On drinking days only[a]	.088 (.06)	.089 (.06)	.084 (.06)	.073 (.05)
Average subjective intoxication				
Across all days	3.22_{a} (6.12)	4.03_{b} (7.13)	4.93_{c} (7.46)	4.69_{c} (6.70)
On drinking days only[a]	27.84_{a} (23.35)	28.21_{ab} (22.80)	25.21_{ab}(21.02)	21.80_{b}(19.75)

Note. Means with differing subscripts within rows significantly differ, $p < .00625$. eBAC= estimated blood alcohol concentration.

[a]Analyses limited to drinking days include *n*s = 881, 893, 958, and 710 participants for years 1–4, respectively.

Table 3

Prevalence of Alcohol-Related Consequences and Behavioral Risks by Year of Daily Monitoring

Variable	Year 1	Year 2	Year 3	Year 4
Alcohol-related consequences	26.72%$_a$	27.03%$_a$	32.51%$_b$	31.45%$_b$
Behavioral risks				
Illicit drug use	13.23%	14.54%	14.22%	12.26%
Sex	32.82%$_a$	37.06%$_b$	38.15%$_b$	37.53%$_{ab}$
Unsafe sex	12.09%	12.15%	13.02%	12.36%
Aggression	25.51%$_a$	18.98%$_b$	16.93%$_{bc}$	12.58%$_c$
Gambling	14.19%$_a$	9.42%$_b$	9.33%$_b$	6.83%$_b$
Property crime	6.81%	5.94%	4.89%	3.90%

Note. Values indicate percentages of participants endorsing outcomes at least once. Percentages with differing subscripts within rows significantly differ, $p < .00625$.

Table 4

Summary of Models Predicting Daily Subjective Intoxication and Alcohol-Related Consequences

	Subjective Intoxication		Alcohol-Related Consequences	
Variable	***b***	**95% C.I.**	***OR***	**95% C.I.**
Between-person				
Male gender	0.32†	0.25, 0.38	0.99	0.89, 1.10
Family history positive	0.15†	0.08, 0.23	1.05	0.94, 1.18
Average eBAC	−0.02*†	−0.03, −0.01	1.00	0.98, 1.03
Average SI	-	-	1.20†	1.10, 1.31
Within-person				
Day of week				
Monday	0.06	−0.06, 0.19	1.00	0.83, 1.21
Tuesday	0.17^	0.04, 0.30	1.11	0.92, 1.34
Wednesday	0.15^	0.02, 0.27	1.10	0.91, 1.33
Thursday	0.36†	0.25, 0.46	1.15	0.98, 1.35
Friday	0.35†	0.25, 0.45	0.98	0.84, 1.13
Saturday	0.19†	0.09, 0.29	0.98	0.85, 1.14
Monitoring day	0.00	0.00, 0.00	0.99†	0.98, 0.99
Monitoring year	−0.09*†	−0.12, −0.06	0.95^	0.91, 0.99
Daily eBAC	0.27†	0.27, 0.27	1.04†	1.03, 1.05
Daily SI	-	-	1.24†	1.20, 1.27
Daily SI × daily eBAC	-	-	0.998^	0.996, 0.999
Daily SI × monitoring day	-	-	1.00	1.00, 1.00

Note. Drinking days only. OR = odds ratio. eBAC = estimated blood alcohol concentration. SI = subjective intoxication.

^ $p < .05$.

* $p < .00625$.

† $p < .001$.

Table 5

Summary of Models Predicting Illicit Substance Use, Any Sexual Behavior, and Unsafe Sexual Behavior

	Illicit Substance Use		Any Sexual Behavior		Unsafe Sexual Behavior	
Variable	***OR***	**95% C.I.**	***OR***	**95% C.I.**	***OR***	**95% C.I.**
Between-person						
Male gender	1.43†	1.27, 1.61	0.59†	0.55, 0.63	0.67†	0.58, 0.76
Family history positive	2.12†	1.87, 2.40	1.31†	1.22, 1.39	1.66†	1.46, 1.88
Average eBAC	0.98	0.95, 1.01	1.02	1.00, 1.04	1.02	0.98, 1.06
Average SI	2.66†	2.41, 2.94	1.32†	1.23, 1.41	1.43†	1.26, 1.62
Within-person						
Day of week						
Monday	0.83†	0.76, 0.90	0.71†	0.67, 0.76	0.74†	0.64, 0.84
Tuesday	0.88^	0.80, 0.98	0.64†	0.59, 0.69	0.61†	0.52, 0.72
Wednesday	0.91	0.81, 1.01	0.65†	0.60, 0.70	0.66†	0.56, 0.77
Thursday	1.02	0.92, 1.13	0.74†	0.69, 0.80	0.71†	0.61, 0.82
Friday	1.28†	1.16, 1.41	1.01	0.95, 1.08	0.98	0.86, 1.13
Saturday	1.28†	1.18, 1.38	1.08^	1.01, 1.13	0.98	0.86, 1.11
Monitoring day	0.99†	0.99, 0.996	0.99*	0.99, 0.998	0.98†	0.98, 0.99
Monitoring year	1.04	0.99, 1.10	1.05*	1.02, 1.07	1.02	0.96, 1.07
Daily eBAC	1.00	0.99, 1.01	0.99*	0.98, 0.997	1.00	0.98, 1.01
Daily SI	1.08†	1.05, 1.10	1.05*	1.02, 1.07	1.08*	1.03, 1.13
Daily SI × daily BAC	1.00	1.00, 1.00	1.003†	1.001, 1.004	1.003^	1.0003, 1.005
Daily SI × monitoring day	1.00	1.00, 1.00	1.00	1.00, 1.00	1.00	1.00, 1.00

Note. OR = Odds Ratio. eBAC = estimated blood alcohol concentration. SI = subjective intoxication.

^ $p < .05$.

* $p < .00625$.

† $p < .001$.

Table 6

Summary of Models Predicting Aggression, Gambling, and Property Crime

	Aggression		Gambling		Property Crime	
Variable	***OR***	**95% C.I.**	***OR***	**95% C.I.**	***OR***	**95% C.I.**
Between-person						
Male gender	0.71†	0.63, 0.79	4.07†	3.52, 4.72	1.55†	1.26, 1.91
Family history positive	1.21*	1.08, 1.36	0.99	0.83, 1.17	1.47†	1.17, 1.85
Average eBAC	1.02	0.98, 1.06	1.09†	1.04, 1.14	1.02	0.96, 1.10
Average SI	1.25†	1.11, 1.41	1.05	0.89, 1.24	1.33^	1.06, 1.66
Within-person						
Day of week						
Monday	0.91	0.78, 1.07	0.94	0.77, 1.15	0.78	0.53, 1.12
Tuesday	0.89	0.75, 1.06	0.83	0.66, 1.05	0.69	0.46, 1.04
Wednesday	0.90	0.75, 1.07	1.03	0.82, 1.29	0.83	0.56, 1.23
Thursday	1.06	0.91, 1.25	1.09	0.89, 1.35	1.02	0.73, 1.43
Friday	1.17^	1.01, 1.37	1.45†	1.19, 1.77	1.10	0.79, 1.53
Saturday	1.33†	1.15, 1.54	1.31†	1.09, 1.59	0.97	0.70, 1.36
Monitoring day	0.96†	0.96, 0.97	0.98†	0.97, 0.98	0.95†	0.94, 0.96
Monitoring year	0.72†	0.69, 0.76	0.69†	0.65, 0.74	0.72†	0.65, 0.79
Daily eBAC	1.02*	1.01, 1.03	1.02^	1.002, 1.04	1.03^	1.00, 1.06
Daily SI	1.00	0.95, 1.05	0.95	0.87, 1.02	0.98	0.89, 1.07
Daily SI × daily eBAC	1.005†	1.003, 1.007	1.00	0.99, 1.00	1.01*	1.003, 1.01
Daily SI × monitoring day	1.005†	1.003, 1.007	1.01*	1.002, 1.01	1.01^	1.001, 1.01

Note. OR = Odds Ratio. eBAC = estimated blood alcohol concentration. SI = subjective intoxication.

^ $p < .05$.

* $p < .00625$.

† $p < .001$.